REVERSE ENGINEERING OF MOBILE PHONE CASING AND ANALYSIS OF WELD-LINE DEFECT

TOH BAN SHENG

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for the award of the degree of
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Universiti Malaysia Pahang

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing Engineering.

Signature	:…………………………….
Name of Supervisor	: En. Asnul Hadi Bin Ahmad
Position	: Lecturer
Date	:………………….…………

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature	: ……………………..…………
Name	: Toh Ban Sheng
ID Number	: ME06044
Date	: ……………………..…………

Dedicated to my beloved parents

and

siblings

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ABSTRACT

In recent decades, reverse engineering (RE) has gradually become important when it comes to the situation that a component must be reproduced but its original engineering data are no longer or not accessible. Sophisticated technologies are introduced for the purpose of reverse engineering. The state-of-the-art technology in latest days is the use of 3D laser scanning with aid of reverse-engineering software to create the 3D geometry model of the existing component. The most appropriate way to duplicate the component is by plastic injection moulding. However, defect such as weld lines always occur during injection moulding process which makes the component aesthetically and structurally unacceptable. Therefore, injection moulding simulation on the component is necessary to investigate the variables that affect the formation of weld lines. Simulations are repetitively done to determine the most optimal variables that remove or reduce weld lines to minimum before the component is ready for reproduction.

ABSTRAK

'Reverse engineering' (R.E) kian memainkan peranan penting dalam zaman sekarang kerana selalu berlakunya bahawa sesuatu produk yang telah wujud perlu dihasilkan semula, tetapi tanpa data asal rekabentuknya. Beberapa teknologi yang canggih telah diperkenalkan untuk tujuan RE. Salah satu teknologi yang terkini ialah cara '3D laser scanning' yang digunakan untuk menghasilkan model geometri 3D produk yang bakal dihasilkan semula. Model geometri 3D amat penting untuk tujuan simulasi pengacuan suntikan. Melalui simulasi tersebut, kecacatan yang terhasil seperti 'weld lines' dapat diperlihatkan. Kewujudan 'weld lines' sedemikian bukan sahaja menjadikan permukaan produk menjadi kurang menarik, tetapi juga menyebabkan ketahanan dan kelasakan pada bahagian 'weld lines'. Maka, simulasi pengacuan suntikan adalah sangat penting untuk menentukan factor-faktor yang mengakibatkan pembentukan kecacatan tersebut. Simulasi dijalankan berulang-ulang kali sehingga pembentukan 'weld lines' telah dihilangkan atau dikurangkan kepada jumlah yang paling minimum.

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LIST OF SYMBOLS

D	Diameter of runner
Ø	Diameter of runner
W	Weight of mobile phone casing
L	Length of runner
°C	Degree Celsius (Temperature)
MPa	Mega Pascal (Pressure)
g	Gram (Mass)

LIST OF ABBREVIATIONS

ABS	Acrylonitrile butadiene styrene
AMA 2010	Autodesk® Moldflow® Adviser 2010
CAD	Computer-aided design
CAM	Computer-aided Manufacturing
CCD	Charge coupled device
CMM	Coordinate measurement machine
LED	Light-emitting diode
RE	Reverse engineering
NC	Numerical control
3D	Three dimensional
USSR	Union of Soviet Socialist Republics

CHAPTER 1

INTRODUCTION

1.1 Introduction

Engineering is the process of designing, manufacturing, assembling, and maintaining products or systems. However, there are two types of engineering, forward engineering and reverse engineering. Reverse engineering differs from forward engineering in such a way that the basic concept of duplicating an existing part based on an original or physical model without the use of an engineering drawings or documentations. Thus, reverse engineering can be known as re-engineering an existing product as well. In such an intensely competitive global market nowadays, product enterprises are constantly seeking novel ways to shorten lead times for new product developments that cater for all consumer expectations. Generally, product enterprise has invested tremendously in computer-aided design and manufacturing (CADCAM) and a wide range of new technologies that provide business benefits. Reverse engineering (RE) is now considered as one of the state-of-the-art technologies that is advantageous in significantly shortening the product development cycle. (Raja et al., 2008).

Reverse engineering of mobile phone casing involves disassembly of an existing mobile phone casing to figure out how it was built and how does it work. The mobile phone casing is undergoing a physical-to-digital process, in which its geometry computer-aided design (CAD) model (digital) is created by scanning the existing object (Lai et al., 1998). Three-dimensional scanners are employed to scan the part geometry capturing information that describes all geometric features such as steps, slots, pockets and holes. The fabricate of the mobile phone casing, injection moulding is the most ideal way as it is a versatile process capable of producing complex shapes with good dimensional accuracy. During the injection moulding, structural defects such as weld lines can occur. These defects can develop in manufacturing processes depending on factors such as materials, part design, and processing techniques. These factors are crucial considerations to be taken in terms of defect elimination.

In recent decades, much progress has been made in the analysis of material flow in injection moulding, Modelling techniques and simulation software has been developed for studying optimum gating systems, mould filling, mould cooling, and part distortion. Software programs expedite the design process for moulding parts with good dimensions and characteristics. The programs take into account such significant factors as injection pressure and temperature (Schmid et al., 2006). The reverse engineering of mobile phone casing project is completed with the simulation of a defect-free injection moulding process.

1.2 Problem Statement

Reverse engineering has been rather common and essential especially when it comes to a situation that the original product design documentation has been obsolete or never existed, some bad features of a product need to be eliminated, analysing the good and bad features of competitors' products, exploring new avenues to improve product performance and features and so forth (Raja et al., 2008). Defect such as weld lines always occur during injection moulding which affect the appearance also has adverse effects on the structural integrity of the products. Thus, this defect has to be removed.

1.3 Objectives

The objectives of "Reverse Engineering of Mobile Phone Casing and Analysis of weld Line Defect" project are to:

i) Create a CAD model of mobile phone casing by using reverse-engineering hardware and software

ii) Investigate weld lines based on injection moulding simulation

1.4 Scope of Study

The scope of study for this project includes the disassembly of a mobile phone casing and creation of its geometry CAD model by employing 3D laser scanner with the aid of *PolyWorks* software which reconstructs the scanned data into a 3D geometry CAD model. The CAD model is imported into *Autodesk® Moldflow® Adviser 2010* software to simulate the material flowing process and to test the manufacturability of the object. Factors of causing weld-line defect are analysed to find out ways such as necessary alterations on the parameter settings in order to remove the weld-line defects.

CHAPTER 2

LITERATURE REVIEW

2.1 Reverse Engineering

2.1.1 Introduction

In common usage in industry, RE often involves taking something apart and analyzing its workings in detail, usually with the intention to construct a new device or program that does the same thing without actually copying anything from the original. But it is important to realise that it is possible to reverse engineer almost any system, even living systems or self-organizing systems that were not “engineered” in the first place, such as a mechanical device, an electronic component, a software program, a living cell or organism, or even a geologic structure. In this sense, reverse engineering is essentially science, using the scientific method as well as measurement, analysis and other tools to gain an understanding of the inner workings and overall function of a system or structure. Thus, sciences such as biology and physics can be seen as reverse engineering of living biological systems' and the physical world respectively (Vinesh et al., 2008).

In the United States and many other countries, even if an artifact or process is protected by trade secrets, reverse-engineering the artifact or process is often perfectly legal as long as it is obtained legitimately. Patents, on the other hand, require a public disclosure of an invention, and therefore patented items don't necessarily have to be reverse engineered to be studied. One common motivation of reverse engineers is to determine whether a competitor's product contains patent infringements or copyright infringements.

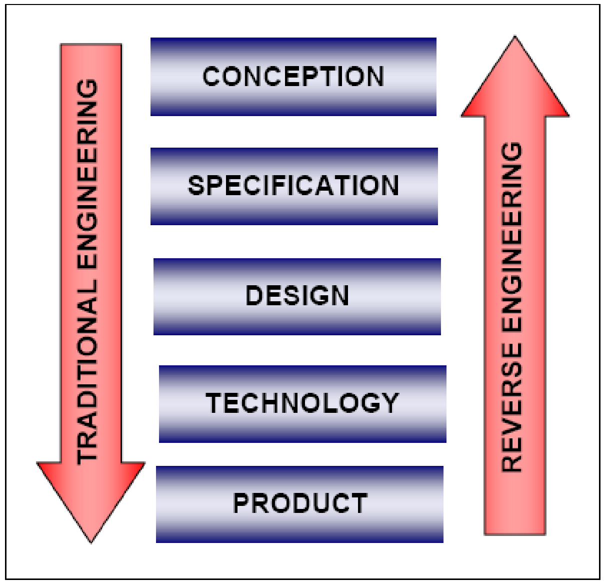

Figure 2.1: Difference between reverse engineering and traditional engineering

Source: Vinesh et al. (2008)

2.1.2 Applications of Reverse Engineering

Reverse engineering can be used in various kinds of fields range from automotive to architecture and medical to software applications. Below are some examples of applications of reverse engineering in different kinds of fields.

In military field, reverse engineering is often used in order to copy technology devices or parts of other nations, which, have been obtained by regular troops in the fields or by intelligence operations. It had been widely used during the Second World War and the Cold War. One of the well-known examples from World War II was "Tupolev Tu-4". A number of American B-29 bombers on missions over Japan were forced to land in the Union of Soviet Socialist Republics (USSR). The Soviets who did not have a similar strategic bomber decided to duplicate the B-29 Superfortress. Within a few years they had developed the Tu-4, a nearly identical duplication. Figure 2.2 and Figure 2.3 show the original U.S. B-29 Superfortress and its reverse-engineered copy, Tupolev-Tu-4 by the Soviet Union.

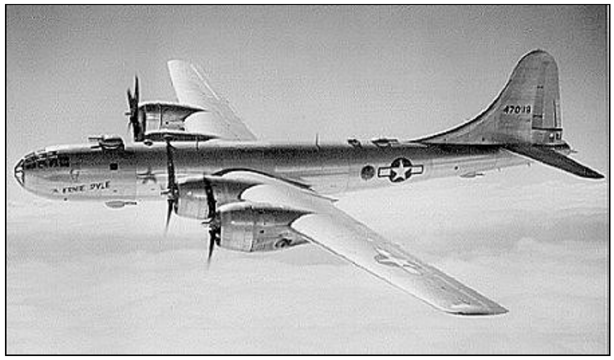

Figure 2.2: Four-engine propeller-driven heavy bomber "The Boeing B-29 Superfortress" flown by the United States Military in World War II

Source: http://www.britannica.com (20 February 2009)

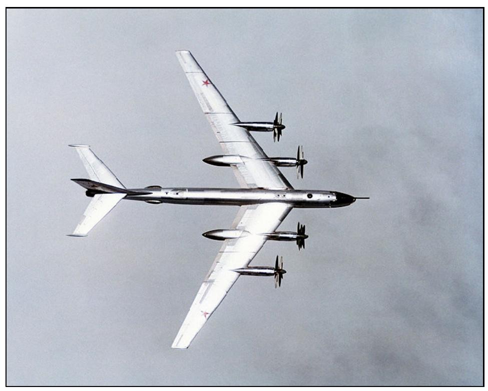

Figure 2.3: Reverse-engineered copy of U.S.-made "The Boeing B-29 Superfortress" by the Soviet Union

Source: http://www.britannica.com (20 February 2009)

In mechanical field, reverse engineering recreates drawings for old parts. For instance, a blade on the impeller of an air compressor breaks off after years of service. But the compressor manufacturer asked for eight months to make a new one. Plant engineers decide to reverse-engineer a new one from the original existing model. The new impeller is milled from an aluminum blank with the toughness and corrosion resistance at least equal to the original. The entire process only consumes three weeks.

In medical field, reverse engineering has been employed in generating data to create dental or surgical prosthetics (artificial body parts which replace missing part), tissue engineered body parts, or for surgical planning. A virtually perfectly custom-fit prosthetic can be duplicated to replace the missing part such as knee joint, femur bones and teeth lost by injury (traumatic) or missing from birth (congenital) or to supplement defective body parts. Figure 2.4 shows how reverse engineering is applied in medical field to produce a prosthetic finger.

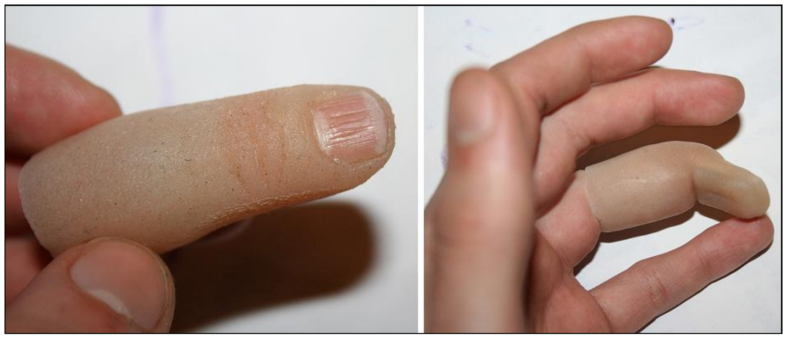

Figure 2.4: Prosthetic finger duplicated by reverse engineering

Source: http://www.prostheticinnovations.com (12 March 2009)

2.1.3 Importance of Reverse Engineering

There are many reasons that reverse engineering has been widely used in numerous applications. When the original manufacturer of a product no longer exists, but a customer needs the product, for instance, aircraft space required typically after an aircraft has been in service for several years. Thus, reverse engineering play a crucial role to create data which has been lost, obsolete or never existed to refurbish or manufacture the desired product. Furthermore, reverse engineering helps in strengthening the good features of a product based on long-term usage by exploring new avenues to enhance product performance and eliminating some bad features of a product. However, there are many more reasons for using reverse engineering than mentioned above (Vinesh et al., 2008).

2.2 Reverse Engineering – The Generic Process

Typically, there are four steps in the reverse engineering process to create a CAD model from an existing real-world object as shown in Figure 2.5.

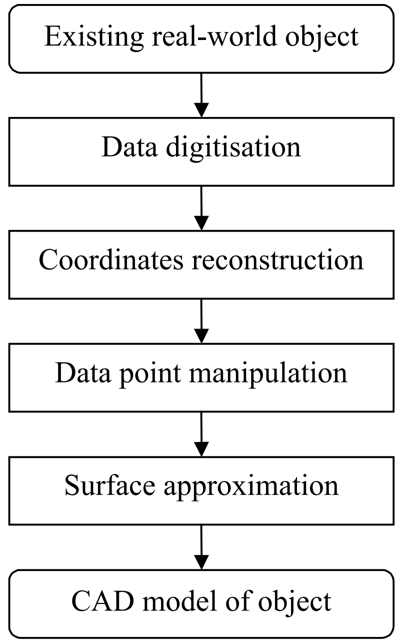

Figure 2.5: Block diagram of reverse-engineering generic process based on the scanning strategy.

Source: Milroy et al. (1996)

2.2.1 Data Digitisation

This phase is involved with the scanning strategy – selecting the correct scanning technique, preparing the part to be scanned, and performing the actual scanning to capture information that describes all geometric features of the part such as steps, slots, pockets, and holes (Raja et al., 2008). Three-dimensional scanners are employed to scan the part geometry, producing clouds of points, which define the surface geometry. There are two distinct types of scanners, contact and non-contact.

The typical 3D CMM is a contact type. In the 3D CMM, the probe slightly touches the surface of the measured part during the scanning process. The 3D profile data in X-, Y-, and Z-directions of the parts are captured as long as the contact pressure is high enough to trigger the sensor to capture signals. Via the computing process, the 3D digitized data of the parts are then recorded for later. This is also known as a "point-